SUMMARY OF ACTIVITIES, NORTH SELKIRK PROJECT GOLDSTREAM RIVER AND DOWNIE CREEK MAP AREAS (82M/8, 9 AND PARTS OF 10)

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KEYWORDS: Downie Creek, Goldstream River, Goldstream mine, Rain, Montgomery, Standard, volcanogenic massive sulphides, garnet zone, Lardeau Group, Badshot Formation.

INTRODUCTION

The Goldstream area, east of the Columbia River in the northern Selkirk Mountains, contains a number of volcanogenic massive sulphide (VMS) deposits, including the operating Goldstream mine, in addition to carbonate replacement, vein and placer gold deposits. The Northern Selkirk project is a two-year study, undertaken to assess and promote the potential for VMS deposits in a 1500 square kilometre area centred 50 kilometres north of Revelstoke, British Columbia (Figure 1). Reconnaissance mapping and lithogeochemical sampling in 1993 will be used to further understand the tectonic setting and, in particular, the age and characteristics of the host succession. Detailed mineral occurrence descriptions will be the focus of the second year and correlating this succession regionally and, hence, evaluating VMS potential elsewhere in the Kootenay Terrane the ultimate goal.

The Northern Selkirk Mountains area is a complexly deformed and metamorphosed region situated between the Foreland fold and thrust belt of the southern Canadian Rockies on the east, and the Shuswap Metamorphic Complex in the west. The Goldstream area is underlain by strongly deformed Late Proterozoic to early Paleozoic metasedimentary and metavolcanic rocks of the Selkirk allochthon, as well as numerous large plutonic bodies, all part of the pericratonic Kootenay Terrane. The Selkirk allochthon consists of at least three tectonic slices (Figure 1). The Goldstream and Clachnacudainn slices form the hangingwall of the Monashee décollement north of Revelstoke. The overlying Illecillewaet slice is the largest and possibly a composite slice making up the easternmost part of the allochthon (Read and Brown, 1981). The allochthon was displaced eastward along the Monashee décollement during Late Jurassic and Late Cretaceous orogenesis; regional extension in the Tertiary localized

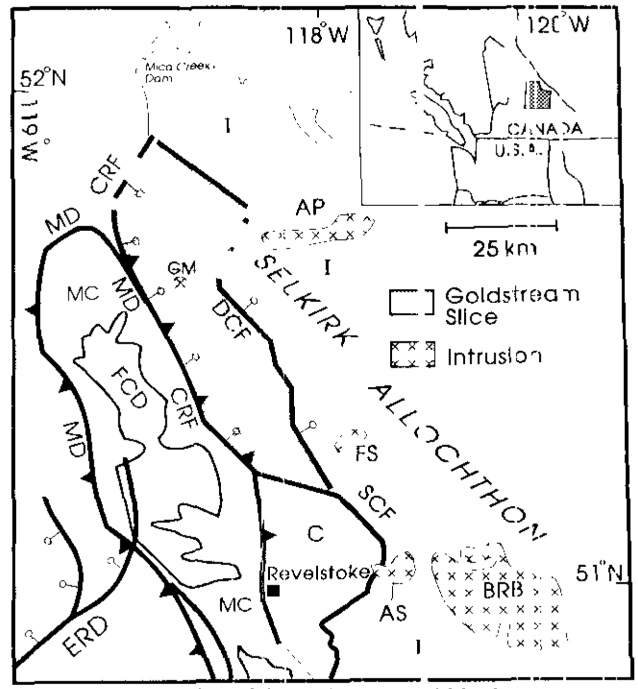

Figure 1. Location of the project area within the Goldstream slice of the Selkirk allochthon, after Brown and Lane (1988). I=Illecillewaet slice, C=Clachnacudainn slice, CRF=Columbia River fault, DCF=Downie Creek fault, ERD=Eagle River detachment, SCF=Standfast Creek fault, MD=Monashee Décollement MC=Monashee Complex, FCD=Frenchman's Cap dome, AP=Adamant pluton, FS=Fang stock, AS=Albert stock, BRB=Battle Range batholith, GM=Goldstream mine.

brittle normal faulting along this same structure (Brown and Lane, 1988).

The geology has been described by numerous authors beginning with Walker and Bancroft (1929), Gunning (1929) and Wheeler (1963, 1965). Read and Brown (1979, 1981), Trygve Höy (1979) of the Geological Survey Branch and R.L. Brown and his students at Carleton University (Brown *et al.*, 1977, 1978, 1983), notably Lane (1977, 1984), have done much work towards understanding the geology and tectonic setting.

REGIONAL STRATIGRAPHY

The Selkirk allochthon is composed of the Upper Proterozoic Horsethief Creek Group, the Eocambrian Hamill Group, the Cambrian Badshot Formation, and the lower Paleozoic Lardeau Group (Wheeler, 1965; Brown *et al.*, 1978). These divisions are broadly similar in lithology, and form the miogeoclinal wedge of ancestral North America, with rocks of the Lardeau Group as a more distal and possible marginal basin sequence to the wedge (Figure 2).

The Horsethief Creek Group consists mainly of phyllitic and slaty pelites, interbedded sandstone, conglomerate and minor carbonate rocks. In the Northern Selkirks, Brown *et al.* (1978) divided them into lower semipelite/amphibolite, middle marble and upper clastic divisions. Unconformably overlying these are Eocambrian Hamill Group rocks consisting mostly of feldspathic and quartzose arenites, which Devlin (1986) interprets as shallow-marine facies sandstones, and mafic metavolcanic rocks (Wheeler, 1963; 1965). Archeocyathid-bearing late Lower Cambrian limestones of the Badshot Formation conformably overly the Hamill Group (Wheeler, 1963).

The Lardeau Group overlies the Badshot in stratigraphic conformity in the Illecillewact synclinorium (Colpron and Price, 1992) and in uncertain and possibly reverse stratigraphic order in the Trout Lake area (Smith and Gehrels, 1992a). In the Ferguson area, Fyles and Eastwood (1962) recognized six formations within the Lardeau Group (Figure 2). The Index Formation is the lowest and consists of dark grey and green, rhythmically bedded phyllite, limestone, minor quartzite and, near the top, phyllitic volcanic rocks. Mafic and ultramafic intrusions (altered to talc schist) occur in the uppermost green phyllites. Above the Index are grey and black siliceous argillites of the Triune Formation, in turn overlain by grey quartz arenite with limy concretions of the Ajax Formation and dark grey siliceous argillite of the Sharon Creek Formation. Fritz *et al.* (1991) interpret these units as outer basinal sediment related to the margin of ancestral North America. Tholeiitic, pillowed and breccia flows, tuff and lesser limestone and phyllite of the Jowett Formation conformably overlie the Sharon Creek Formation. Grey quartz-feldspar grit, foliated micaceous quartzite and phyllite of the Broadview Formation form the uppermost part of the Lardeau Group. Fritz *et al.* (1991) propose a western source, outboard of ancestral North America, for the sands of the Broadview Formation.

Carboniferous Milford Group basal conglomerate, limestone, tholeiitic volcanics and siliceous argillite lie with angular unconformity on the Broadview Formation (Figure 2). Boulders of the Broadview Formation from the basal conglomerate of the Milford Group yield an Early to Middle Ordovician Rb-Sr

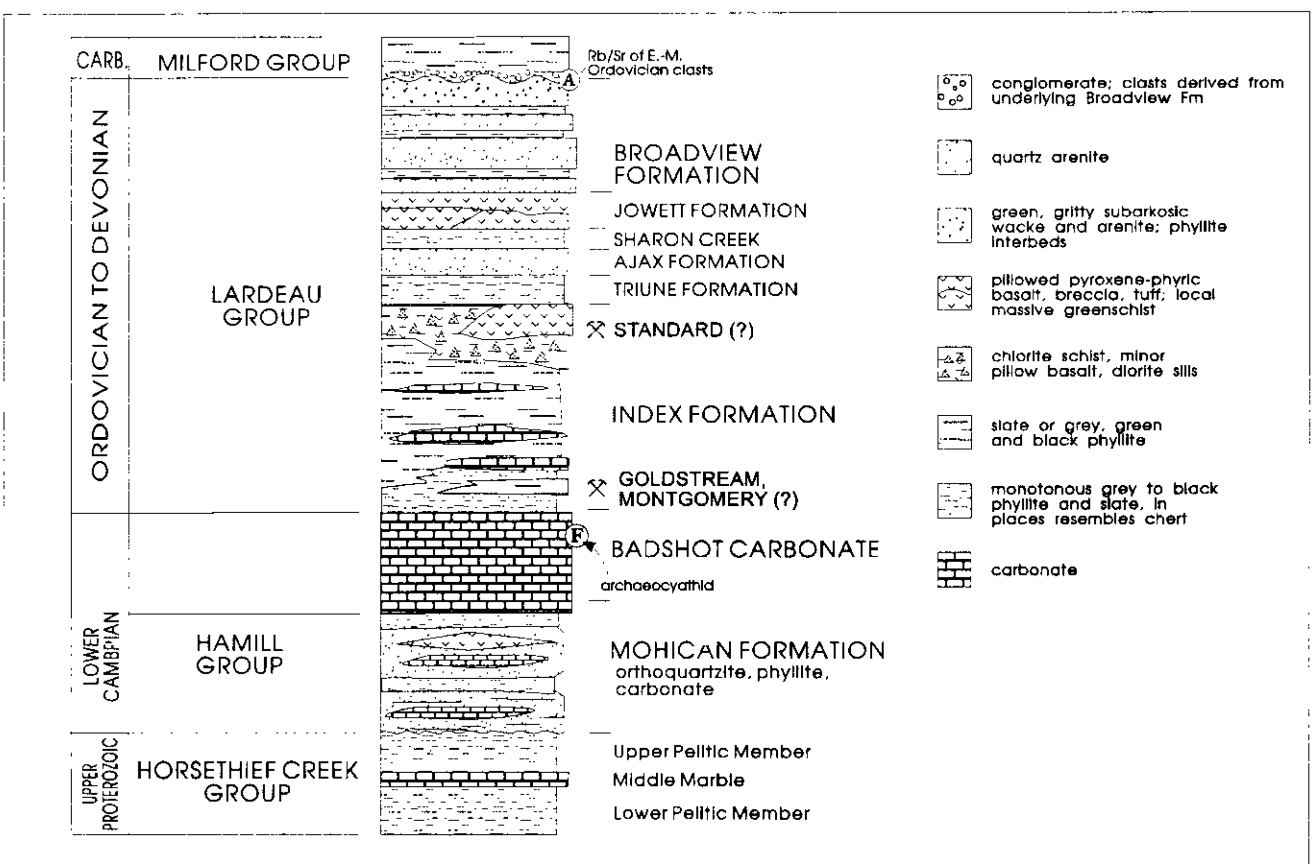

Figure 2. Schematic stratigraphic column of the Lardeau Group and underlying rocks, after Fyles and Eastwood (1962) and Brown *et al.* (1978). The Triune, Ajax, Sharon Creek and Jowett Formations of the Lardeau Group, and the Milford Group are not recognized in the study area. The relative thickness of the Lardeau Group is exaggerated for clarity.

whole-rock isochron date (Read and Wheeler, 1977).

GOLDSTREAM SLICE LAYERED ROCKS

The stratigraphy of the Goldstream slice is dominated by pelitic rocks with interlayered carbonate horizons; quartzite and grit, carbonate, impure psammite and volcanic rocks. Wheeler (1965) showed much of the area to be underlain by Lardeau Group rocks, however specific correlations and stratigraphic definition within the slice are made difficult by the following problems:

- The Goldstream slice is entirely fault bounded.
- The absence of fossil-bearing strata.
- Lithological similiarities between the Horsethief Creek, Hamill and Lardeau Groups
- Structural complexities resulting from repeated deformation.

Consequently, the stratigraphic nomenclature has evolved through many changes and stratigraphy is yet to be firmly established.

Wheeler assigned the rocks north of the Goldstream River to the Horsethief Group, which subsequent workers supported (Franzen, 1974; Brown *et al.*, 1977). More recent work by Gibson and Höy (1985) and Gibson (unpublished) suggest this area is underlain by younger rocks of the Hamill Group, Badshot Formation and Lardeau Group (Figure 3). Reconnaissance mapping this summer in the Groundhog Basin north of Goldstream River identified a package of well-sorted, graded beds of quartz-feldspar grits, quartzite and micaceous quartzite, black sericite schist and calcareous phyllite with lesser greenstone, talc schist and carbonate. Assigning these rocks to either stratigraphic sequence will require further work. Stratiform zinc-lead massive sulphide mineralization in possible equivalent at the Rift showing (12 km north of the map area) gives galena-lead model ages of Early Cambrian to Late Hadrynian (approximately 0.52 Ga; Hicks, 1982) supporting a younger age for the strata.

South of the Goldstream River, the westernmost Lardeau Group rocks were assigned to the Broadview Formation by Campbell (1972). Later, Brown *et al.* (1976), Lane (1977) and Höy (1979) considered the rocks to the east to belong to the upper Horsethief Creek and Hamill groups. On the basis of overturned stratigraphy, they proposed the following stratigraphic sequence: an older carbonate-pelitic schist unit, a middle mixed unit of impure psammite and pelite with metavolcanic rocks, and a younger carbonate-pelitic schist unit. These units were tentatively correlated with the Horsethief Creek Group, the Hamill Group and Badshot Formation - Lardeau Group, respectively. Höy (1979) further divided the middle mixed unit into a lower quartzite-schist division, a calcsilicate gneiss division and a metavolcanic-phyllite division, correlating the latter with the Mohican Formation, the upper part of the Hamill Group in the Kootenay Arc.

Latest work by Brown *et al.* (1983), Höy *et al.* (1984), Brown and Lane (1988) and Brown (1991), show Hamill Group, Badshot Formation and Index, Jowett and Broadview formations of the Lardeau Group traceable north from Carnes Creek to Downie Creek (Figure 3). Gibson (1989) mapped Mohican and Marsh Adams formations of the Hamill, the Badshot Formation and Index Formation of the Lardeau Group in the area between Goldstream River and Downie Creek.

Using these most recent stratigraphic correlations we spent the summer measuring sections of apparently well constrained stratigraphy. The purpose of measuring sections was more to determine the relative proportion and distribution of lithologies then true thickness. Composite stratigraphic sections of the lower Lardeau Group rocks were measured in the area between the Goldstream River and the Goldstream mine and on the west and east limbs of the Downie Peak antiform (RS, DP and LC, Figures 4 and 5). In addition, stratigraphic sections were measured in four areas of known copper-zinc volcanogenic massive sulphide occurrences.

SECTION RS

Three separate units comprise the stratigraphy measured northwest of the Goldstream pluton (RS). They include a structurally lowest micaceous quartzite-phyllite unit, chlorite schist and black phyllite, and an uppermost dolomitic marble. The quartzite-phyllite unit crops out along Highway 23 north of the Goldstream mine turn-off for 4.5 kilometres; at 5 kilometres from the turn-off the black phyllite crops out, followed by the marble unit at 6 kilometres. The stratigraphy is shown in Figure 4, and described in ascending structural order.

The quartzite-phyllite unit is comprised of rhythmic beds of greenish quartzite and green sericite-chlorite phyllite. Micaceous quartzite predominates and the proportion of quartzite to phyllite is greater than 1, generally on the order of 4. Bedding is planar, ungraded and varies from a centimetre to several metres thick. The unit is disrupted by folding and faulting and zones of argillic alteration. Thick metre-scale quartzite beds are thoroughly fractured, phyllite is crenulated and rusty weathering.

Structurally overlying the quartzite-phyllite is a succession of dark green, massive to phyllitic chlorite schist, interbedded sericite schist, quartzite and limestone, and dark phyllite exposed on secondary roads branching north from the Goldstream mine road, 5.5 kilometres from Highway 23. The chlorite schist is well foliated, contains carbonate partings and stringers and several percent euhedral pyritohedrons. It is overlain by a thinly bedded mixed unit of sericite-chlorite schist, marble and micaceous quartzite, which grades upwards into dark phyllite. Five metres of

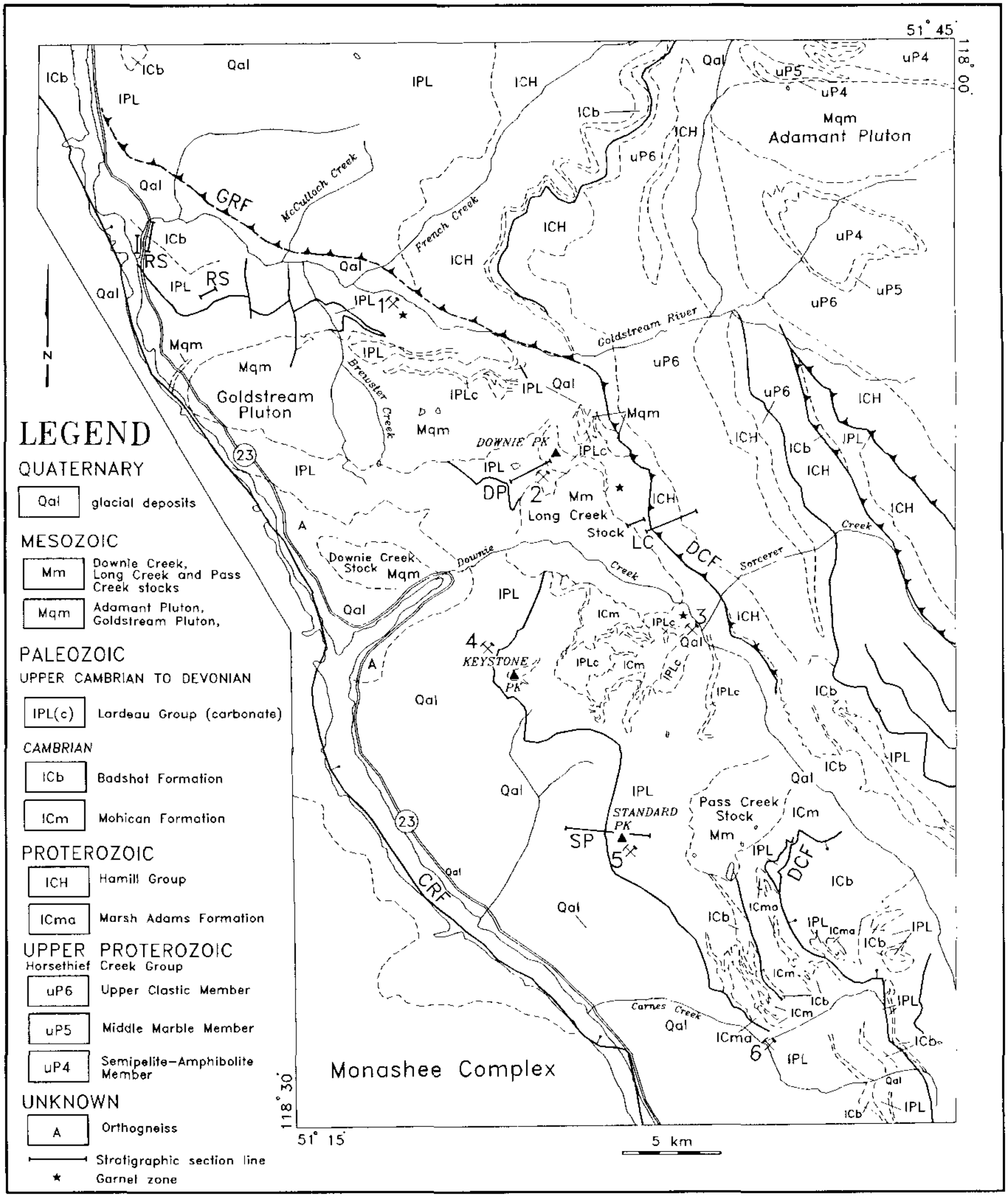

Figure 3. Geological map of the project area, modified from Gibson and Höy (in press). Mineral occurrences are shown by pick and hammer symbol: 1=Goldstream mine, 2=Montgomery, 3=Rain, 4=Keystone, 5=Standard, 6=J&L. Stratigraphic section lines: RS=Road and Goldstream River estuary outcrops (measured), DP=Downie Peak (measured), LC=Long Creek area, SP=Standard Peak. DCF=Downie Creek fault, CRF=Columbia River fault, GRF=Goldstream River fault.

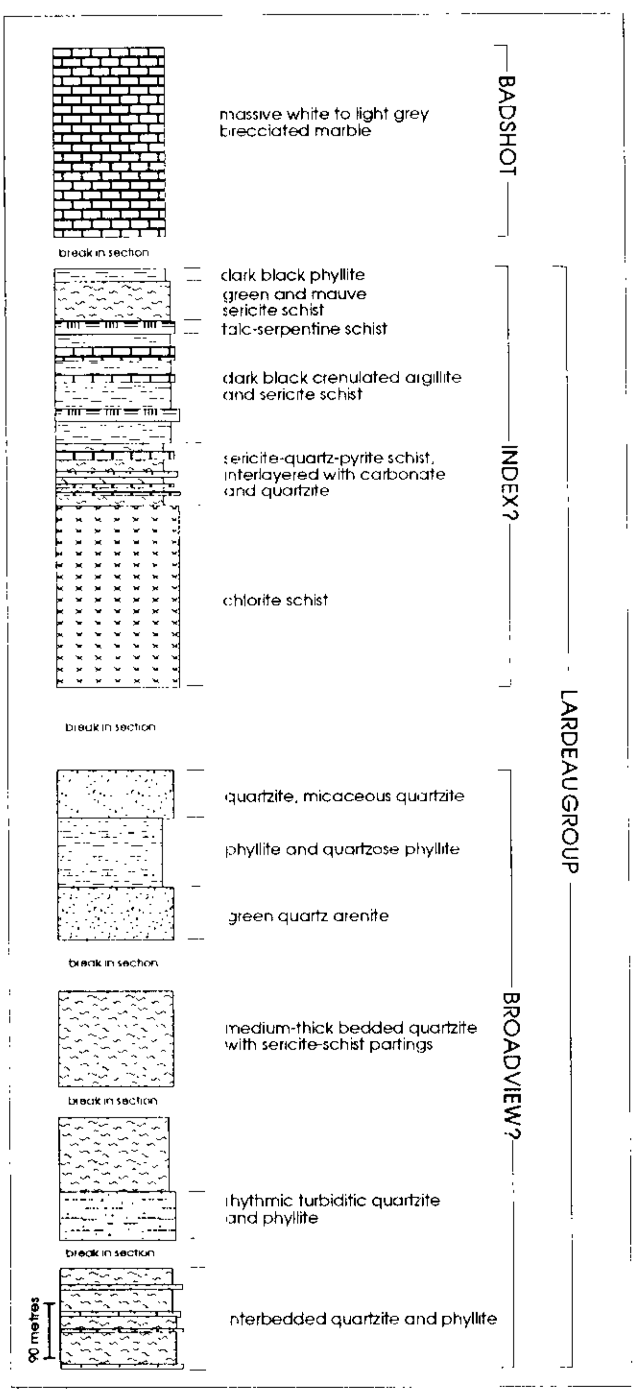

Figure 4. Schematic stratigraphic section compiled from measured outcrops along the Goldstream River estuary, Highway 23 and Goldstream mine road. The section is shown as structurally upright; stratigraphic correlations suggest this succession is inverted.

serpentine-antigorite schist within dark, banded phyllite are exposed in a soapstone quarry.

A structurally thickened package of dark, banded phyllite crops out along Highway 23, on strike with these phyllites. Talcose altered ultramafic rocks form the base of the section. The unit has been structurally interleaved with black calcareous and carbonaceous phyllite which contains brilliant green, coarsely crystalline fuchsite adjacent to the ultramafites. Dark, thinly interbedded, silty argillite and phyllite comprise most of the road cut. The dark, banded phyllite is intruded by two, talc-antigorite-ankerite schist units, both approximately 3 metres wide. Ten metres of rhythmic bedded, dark and light brown marble are exposed near the top of the section. The marble is interbedded with, and overlain by, sericite schists and grey phyllite similar to those at the lower contact. Thinly bedded white carbonate with green and mauve sericitic schist partings overlies black graphitic sericite schists in the Goldstream River. To the east (up structure) are sericite schists, sericite psammites, micaceous quartzite horizons and lesser black graphitic phyllite. Black sericitic phyllite forms the uppermost unit below the massive marble of the Badshot Formation; the contact is not exposed. The marble is bright white to cream coloured and finely crystalline to amorphous. It is commonly dolomitic and, where not interbedded with phyllite or sericite schist, crops out as spectacular white carbonate massifs.

Lithologically the quartzite-phyllite, black phyllite and marble units (Figure 4) are similar to the Hamill, Mohican and Badshot formations, an upright-facing succession. However, we agree with Gibson's (1989) correlation of these rocks with the Broadview, Index and Badshot formations, and the section therefore represents an inverted stratigraphic panel. More important is the correlation of black phyllite with the dark, banded phyllite which hosts the massive sulphide horizon at the Goldstream mine.

SECTIONS DP AND LC

Lardeau Group stratigraphy was measured along the southwest flank of Downie Peak (DP). East of Long Creek a second section (LC) started in correlative units and continued eastward. Previous workers recognized Downie Peak as a second phase antiformal syncline cored by carbonate of the Badshot Formation (Brown *et al.*, 1977; Höy, 1979; Gibson, 1989); thus, a stratigraphic symmetry should be apparent across east and west limbs. However, our observations (Plate 1) and measured stratigraphic sections (Figures 3 and 5) suggest the stratigraphy is asymmetric on either side of Downie Peak, and we believe the carbonate may be of the Index Group

The section west of Downie Peak began on the ridge east of Boulder Creek at an elevation of 1890 metres (6200 feet), ending 150 metres (500 feet) below the limestone which forms the summit at 2928 metres (9607 feet). It is a coarsening-upward sequence dominated by (1100 m) quartz-biotite and quartz-sericite schists interlayered with marble at lower elevations. This passes gradationally upwards through schist, quartzite and grit with lesser carbonate (650 m) to a micaceous quartzite unit (250 m) which is abruptly overlain by white marble forming the top of Downie Peak.

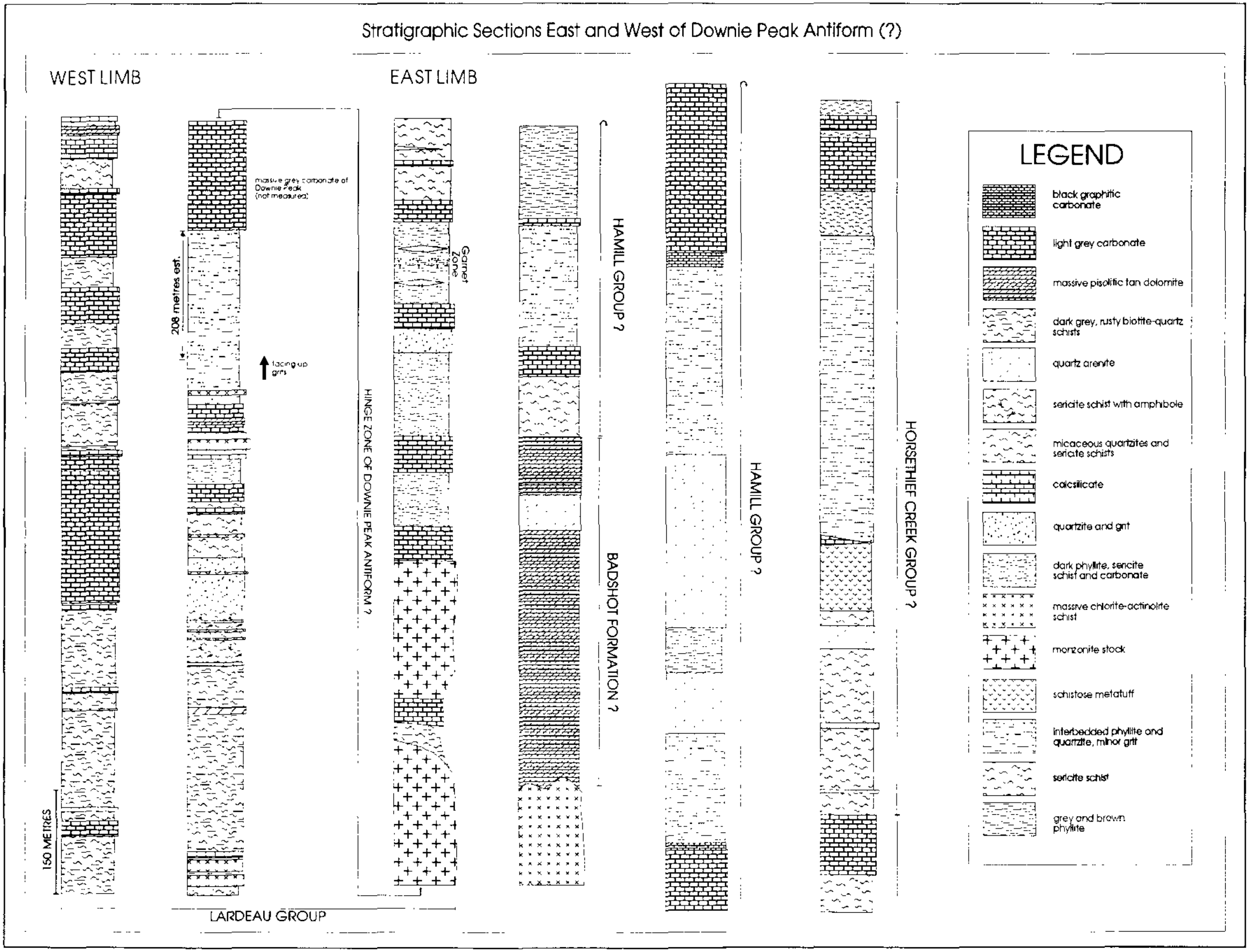

Figure 5. Schematic stratigraphic sections of rocks west of Downie Peak (measured) and east of Downie Peak (compiled from cross-sections). Note that the Long Creek pluton disrupts the stratigraphy east of Downie Peak, which is not easily correlated with stratigraphy west of the peak.

Plate 1. View of Downie Peak from the south. Note the gradational upper contact and sharp lower contact between the massive carbonate and adjacent quartzites and schists.

A thick carbonate unit (200 m) comprised mainly of grey marble and buff phyllitic carbonate separates the schist-carbonate package into lower biotite schist and upper sericite schist units. Pelitic schists of the lower package are mainly thinly foliated, dark grey to brown in colour. Carbonaceous schists are rare and calcareous schists are gradational to marble layers. Biotite-quartz schist contains numerous lenticular and sigmoidal augens of grey and yellow quartz. Quartz-rich layers contain trace amounts of disseminated pyrrhotite. Elongate metablasts (5 cm) of andalusite(?), now retrograded to muscovite and quartz, are common but bedding (composition) specific. Above the marble unit are roughly equal proportions of interlayered phyllitic carbonate and sericite-quartz schist which, near the top, contain interbeds of micaceous quartzite and metadiorite bodies. Lithologies are interbedded on a centimetre scale. Schists are pale green to silver and contain actinolite(?) porphyroblasts on S_2 foliation planes. Carbonates include grey, black and brown marbles and phyllitic limestone. Coarse-grained, dark green metadiorite sills intrude the sediments near the top of the unit at low angles to foliation. These bodies are up to 20 metres thick; boudins less than a metre thick were noted within marble to the west of the section. Textures vary in the thicker sills from massive to intersertal in the centre, to schistose and mylonitic near the margins.

A coarsening-upward package of clastic rocks overlies the carbonate-schist unit. It begins with interbedded quartzite and schist, followed by micaceous quartzite which grades upward into interbedded grit and quartzite. Graded bedding at three locations indicates upright-facing units. Quartzites are pale grey, rarely pink and medium to fine grained. Schists contain matted clusters of centimetre-long amphibole porphyroblasts. A single dolomite layer occurs within micaceous quartzites low in the clastic sequence, while substantially more phyllitic carbonate is exposed near the top, where it is interbedded with quartz arenite, schist and grit. Grit beds commonly contain millimetre-size plagioclase and quartz grains in a finer grained, wacke matrix. The upper clastic unit consists of metre-scale interbedded quartzite, schist and grit and is distinctive due to its lack of carbonate. The unit coarsens upward, beginning with thin interbedded clean quartzite and schist, which become thicker bedded and interbedded with grit and micaceous quartzite. The section stopped 180 metres below the upper contact with the white marble of Downie Peak. Total thickness was calculated from airphotos.

The section east of Long Creek (LC) starts in quartz monzonite of the Long Creek stock and extends east, up-structure but apparently down section, through approximately 4300 metres of rocks of the Lardeau Group, Badshot Formation (?), Hamill and possibly Horsethief groups. The section line crosses the Downie Creek fault which separates the Goldstream and Illecillewaet tectonic slices (Read and Brown, 1981).

Rocks of the Lardeau Group include a lower package of biotite-hornfelsed graphitic and pyrrhotitic phyllite, muscovite schist and interbedded marble (in part altered to calcsilicates), with lesser quartzose phyllite and micaceous quartzite. Sericite schist with lath-shaped porphyroblasts, micaceous quartzite and buff phyllitic carbonate comprise the structurally higher package. The garnet zone is projected into the section from 1 kilometre to the north, where it consists of thin-laminated siliceous spessartine-bearing graphitic phyllites, cherty and micaceous quartzites. The unit is fault bounded where it crops out (Figure 3). The structural top of the Lardeau schist-carbonate unit and the base of the Badshot Formation are intruded by dark green, massive to thinly foliated metadiorite sills (Figure 5). The greenstone is well cleaved and contains foliation-parallel patches of chloritic biotite crystal aggregates.

The structurally lowest carbonate of the Badshot Formation is a buff-weathering, fine-grained and thinly foliated dolomite. It is a pristine pisolitic dolomite above the metadiorite sill, where it mainly consists of concentric-layered, brown, ovoid pisoliths 5 millimetres in diameter within a white to buff cryptocrystalline dolomitic matrix (Plate 2). The excellent preservation of these primary sedimentary textures probably reflects a strain shadow developed adjacent to the massive diorite sill. The pisolites are good shallow-water paleoenvironmental indicators; pisoliths (pisolite-bearing carbonate) are currently believed to form by diagenesis in the vadose zone (Blatt *et al.*, 1980).

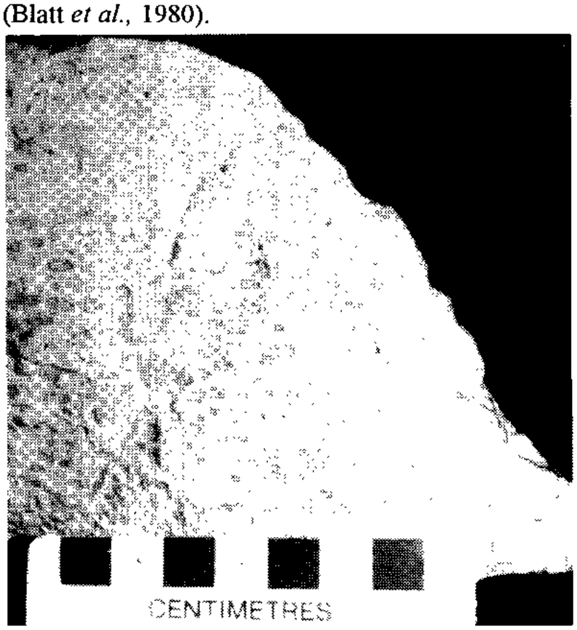

Plate 2. Well-preserved pisolitic dolomite from the section east of the Long Creek stock.

Quartz arenites, sericite schist and quartz-bearing dolomite are interbedded with the top of the dolomite. Thinly foliated, phyllitic dolomite, similar to the lowest dolomite, is gradational upwards into sericite schist, quartzite and phyllite, green-grey phyllite and light grey marble. We agree with Brown *et al.* (1978) that these rocks are probably Hamill Group, as shown on Figure 5. They are overlain, in turn, by a relatively thick unit of micaceous quartzite, quartz arenite, phyllite and grey marble, which may outline a synform, based on a repetition of stratigraphy (Figure 5). We also include this predominately quartzitic unit in the Hamill Group.

Overlying the grey marble (perhaps Mohican Formation of the Hamill Group), is a more heterogeneous package of sericite schist, quartzite, interbedded schist and quartzite, green metatuff and marble (Figure 5). Brown *et al.* (1978) assigned these rocks to the Horsethief Creek Group.

INTRUSIONS

The Goldstream pluton is a complex of quartz monzonite sills and pendants of layered country rock. The intrusion consists of a mafic phase of hornblende-biotite quartz monzonite and a relatively younger, more felsic phase of biotite quartz monzonite. The margins of the intrusion are defined by east-west aligned hornfelsed or skarned pendants and inclusions of country rock. The inclusions show various stages of assimilation, but notably all are penetratively foliated. The age of the complex is unknown. A folded foliation in the quartz monzonite (Höy, 1979) has been interpreted to suggest a pre-phase 2 deformation, possible Devonian age for the intrusion. We feel that the presence of penetratively foliated country rock inclusions within the Goldstream intrusion suggests it postdated development of foliation and probably belongs to the Middle Jurassic suite of intrusive rocks.

The Adamant pluton, also east trending (Figure 3), is a composite body of hypersthene-augite monzonite with a hornblende-rich border (Fox, 1969). Foliation parallels enclosing Horsethief Creek metasediments and Fox suggests the body was emplaced prior to or during regional metamorphism and deformation. Concordant zircon ages (167-170 Ma; Shaw, 1980) have been interpreted to be synmetamorphic (Shaw, *op.cit.*); alternatively the ages may reflect a Middle Jurassic age for the pluton (Woodsworth *et al.*, 1991).

Younger(?), roughly circular stocks of mainly potassium feldspar porphyritic granite and quartz monzonite crosscut phase 2 structures and associated metamorphism. They are post-tectonic, undeformed intrusions of Middle Jurassic age and include the Fang pluton (168±2 Ma, Brown *et al.*, 1992), Pass Creek pluton (168±3 Ma, Brown *et al.*, 1992), the Downie Creek stock and Long Creek stock. Tungsten skarn mineralization occurs in calcareous country rocks adjacent to the Long Creek stock (Vanderpool, 1982).

STRUCTURE

Earlier workers (Lane, 1977; Höy, 1979; Read and Brown, 1979) have suggested that second phase folds deform previously inverted stratigraphy and, in the Goldstream slice, strata occupy the inverted limb of an early nappe that has undergone two subsequent phases of deformation (Brown *et al.*, 1983). Phase 1 deformation has produced westerly verging kilometre-scale nappes and westerly directed thrust faults. The Scrip nappe (Raeside and Simony, 1983) and Carnes nappe (Brown and Lane, 1988) formed during this phase of pre-Middle Jurassic deformation. Upper age constraints on phase 1 deformation include a Middle Jurassic, 168 Ma date for the Pass Creek pluton which intrudes the upper limb of the Carnes nappe (Brown *et al.*, 1992). Map-scale phase 2 folds include the Downie Peak, Keystone and Standard antiformal west-verging structures. Phase 2 folds are tight to isoclinal, overturned to recumbent and characterized by axial plane schistosity which regionally dips either east, northeast or northerly. Axial surfaces plunge at moderate angles to the northeast. Phase 2 folding is synmetamorphic. Phase 3 folds are east-trending, open chevron and kink folds which deform S_2 schistosity.

Major faults bound the study area and define the Goldstream slice. Along its western margin, the Monashee décollement and Columbia River fault zone separate the hangingwall Goldstream allochthon from the footwall rocks of the Monashee Complex. The eastern boundary of the allochthon is marked by the Downie Creek fault, a normal, east-side-down fault along its southern trace (Brown, 1991). North of Downie Creek, this structure curves west into the Goldstream valley and changes from an east-dipping to a north-dipping reverse fault (Goldstream River fault). East of the Long Creek stock, the bounding fault separates the Hamill Group from the Lardeau Group (Figure 3). However, we observed gradational contacts between these two groups, rather than a structural break, in section line LC, and question the location of the Downie Creek fault.

At Nichols Creek (north of the map area), the structure trends north again into the Columbia River fault zone (Read and Brown, 1981; Gibson and Höy, 1985). A less understood, sinuous north-trending structure divides the allochthon. Brown (1991) denotes it as the westerly directed Standard thrust fault. South of Goldstream River it is described as a pre-S_2 (?) slide fault (G. Gibson, personal communication, 1993).

METAMORPHISM

Most of the Goldstream slice has undergone greenschist facies (chlorite zone) metamorphism, with local exceptions. Most significantly, rocks lying between Goldstream River and Downie Creek are higher in grade, and range from the amphibolite facies to the biotite zone of greenschist facies. The elevated grade is probably related to intrusion of the late syn-D_2 to post-D_2 Goldstream pluton. Coarse, elongate porphyroblasts of fine-grained quartz and muscovite are a major constituent of many of pelitic schists in the Caribou Basin area. We interpret these as andalusite pseudomorphs, although Höy (1979) described them as possible kyanite pseudomorphs.

Pelitic schists around the Goldstream pluton are also characterized by coarse (up to 10 cm long), dark grey, flattened laths of an unknown mineral, thought to be either actinolite, andalusite or stilpnomelane (Plate 3). It occurs with fine, millimetre-scale black actinolite randomly dispersed on S_2 foliation planes. The crystal habit varies subtly from area to area and more than one mineral may be present.

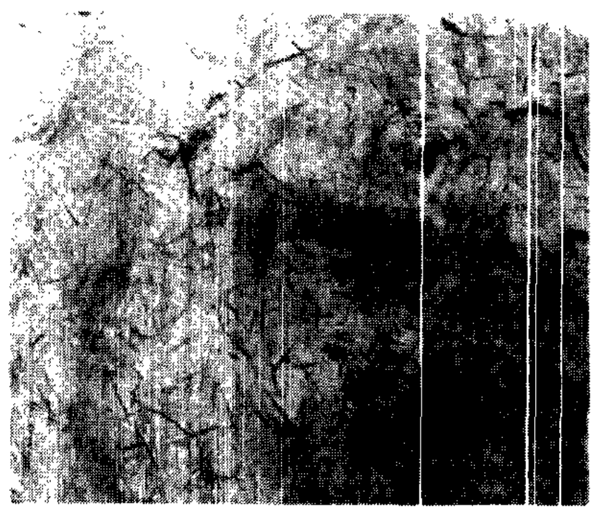

Plate 3. Radiating clusters of elongate porphyroblasts on foliation surfaces of impure pelitic schist. These crystals may be actinolite.

MASSIVE SULPHIDE DEPOSITS

Mineral deposits within the Goldstream allochthon include a wide spectrum of deposit types, from volcanogenic massive sulphide (the focus of this study) to lead-zinc carbonate replacement, tungsten-copper skarn, base and precious metal quartz veins, placer gold and placer concentrations of garnet. Although exploration on some of these deposits began before the turn of the century (e.g. Standard), the area remains under explored and highly prospective for volcanogenic massive sulphide targets.

Three copper-zinc massive sulphide deposits and one prospect occur within the study area (Figure 3, Table 1). To understand the setting of these deposits, stratigraphic sections were measured, or drill-core logged and samples collected for trace element geochemical analysis. Sections include the east wall of the Goldstream mine pit, the Standard Peak area

TABLE 1. MASSIVE SULPHIDE OCCURRENCES WITHIN THE STUDY AREA.

DEPOSIT (MINFILE)	TYPE	HOST	MINERALS	RESERVES
GOLDSTREAM (141)	Besshi VMS	dark graphitic sericite schists, green phyllite, chlorite schist (greenstone), serpentinite intrusions	po, sph, cp	1.436 mt @ 4.48% Cu, 3.03% Zn (News release, May 13, 1993)
MONTGOMERY (85)	Besshi VMS	calc-silicate, dark graphitic and cherty sericite schist	po, sph, cp	1 to 3.5 metres thick over 750 metre strike length (Campbell and Lewis, 1991)
RAIN (156)	Besshi VMS ?	black graphitic and cherty sericite schist	po, cpy	
STANDARD (166)	Besshi VMS	chlorite schist and talc-serpentine ultramafic rocks	py, po, cpy, sph	
C-1,2,3	stratabound	dark graphitic sericite schists, green phyllite	gl, sph	

VMS=volcanogenic massive sulphide,; cp=chalcopyrite, gl=galena, po=pyrrhotite, py=pyrite, sph=sphalerite

and drill core from the Rain property and Montgomery showing (1, 3, and SP, Figure 3).

GOLDSTREAM MINE

Copper-zinc mineralization was discovered at Goldstream during construction of logging roads in 1972. Local prospectors Frank King, Gordon and Bruce Bried staked claims the following year and tested the showing with X-ray-drill holes and hand trenching. The Noranda Group acquired the property in 1975 and completed 8912 metres of diamond drilling, outlining 3.175 million tonnes of ore grading 4.49 % copper, 3.24 % zinc and 20 grams per tonne silver. The portal was collared the next year and an adit driven south to the ore zone. Drifting proceeded east and west along the orebody and 40 underground diamond-drill holes were completed below the 700-metre level. The production decision was made in 1980 and the mine opened in 1983. Depressed metal prices forced closure less than a year later.

Bethlehem Resources Corporation and Goldnev Resources Incorporated acquired the Goldstream property from Noranda in 1989. Production began again in May 1991. The mine is currently producing

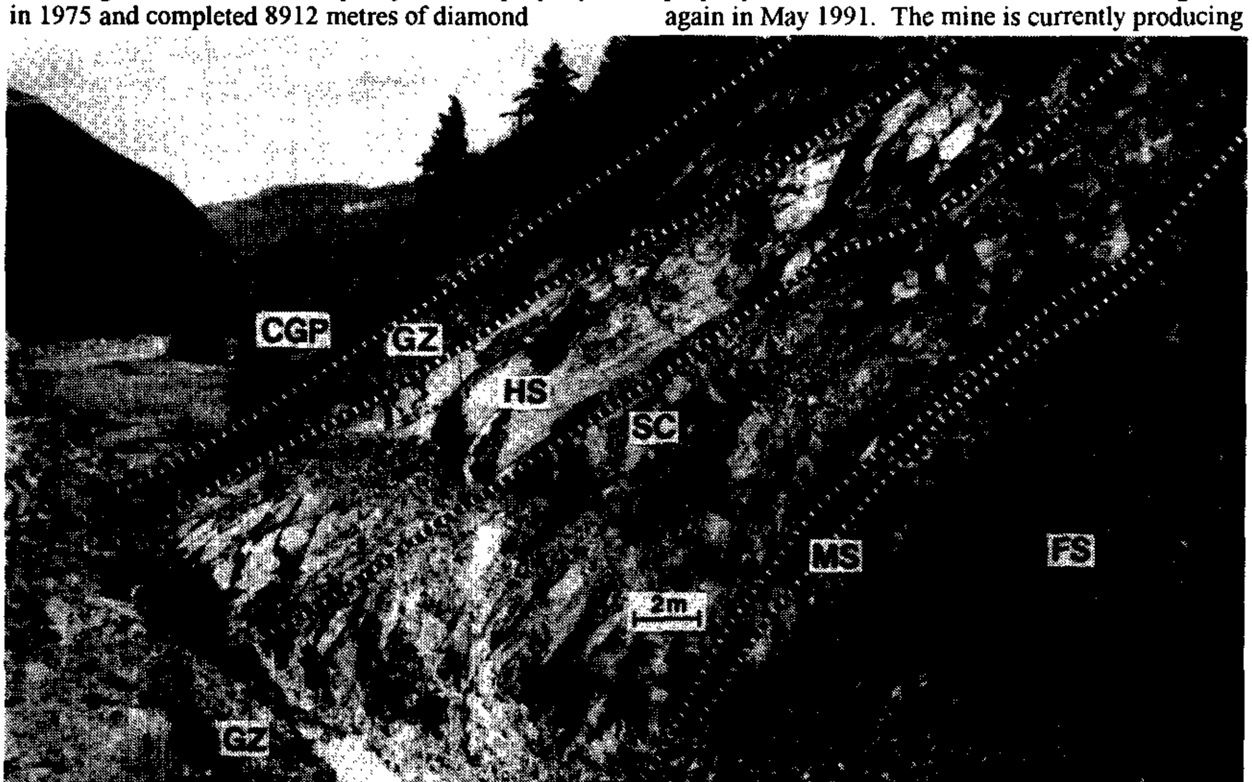

Plate 4. Goldstream mine open pit, viewed to the east. These rocks are described in the measured section of Figure 6. CGP=calcareous graphitic phyllite, GZ=garnet zone, HS=hangingwall schist, SC=silicified carbonate, MS=massive sulphides, FS=footwall schist.

at a rate of 1150 tonnes per day. Ore reserves are 1.436 million tonnes grading 4.48% copper and 3.03% zinc (News Release; Vancouver Stock Exchange, May 13, 1993).

The Goldstream deposit is within a mixed package of black graphitic and sericite schist, carbonate and less quartzite and greenstone. Approximately 50 metres of the mine sequence stratigraphy is exposed along the east wall of the open pit (Figure 6 and Plate 4). Strata dip moderately to steeply north into the east-trending pit; the sulphide horizon plunges gently northeast. Regional structures suggest the succession is inverted (Höy *et al.*, 1984), with the oldest rocks in the hangingwall.

The uppermost rocks in the open pit are tightly folded and faulted, black, thinly bedded, carbonaceous and quartzose phyllite, calcareous phyllite and phyllitic carbonate. Pyrrhotite is ubiquitous. The rocks are well indurated and contain quartz veinlets and augen. Five metres of dark green and mauve chlorite(?)-sericite schists underlie the dark, banded phyllite unit in gradational contact. The 'garnet zone' is a distinct brown-weathering, thin-bedded, but highly resistive siliceous unit It contains rhythmic millimetre to centimetre-scale layers of graphitic, calcareous chert, chloritic phyllite and locally abundant spessartine garnet. Pyrrhotite occurs as wispy laminations and blebs and grunerite occurs in some dark siliceous layers (Höy *et al.*, 1984). The upper and lower contacts are gradational with quartzose phyllites and sericite-rich greenish and mauve schist. A 20-metre unit of mainly silver-weathering, mauve sericite-muscovite schist contains the massive sulphide layer. There is a 5-metre section of silicified interbedded marble, schist and quartzite, which contains disseminated pyrrhotite, chalcopyrite and sphalerite in the hangingwall of the massive sulphide layer . Sulphide concentration increases downwards toward the massive sulphide horizon, which is about 1.5 metres thick and consists of a disseminated sulphide zone (0.3 m), a quartz and chalcopyrite-rich zone (0.3 m) and a massive pyrrhotite, sphalerite and chalcopyrite zone. Footwall marble is a medium to dark grey, banded carbonate interbedded with rusty sericitic phyllite and quartz segregations. Massive to schistose fine-grained greenstone is exposed at the west end of the pit. The rock is composed of actinolite, chlorite, epidote and albite, and interpreted to be a basic volcanic unit (Höy *et al.*, 1984). It correlates with chlorite schist farther northwest which may represent a thick intrusive body.

RAIN

The Rain property is located between Standard and Murder creeks south of Downie Creek. It is underlain by Lardeau Group graphitic phyllite, sericite schist and carbonate similar to the host stratigraphy at the Goldstream mine Diamond drilling has intersected manganese-enriched, garnetiferous and sulphide-bearing zones that may correlate with the garnet zone at the Goldstream mine (C. Wild, personal communication, 1993). Two drill holes were logged from the 1992 drilling and limited surface mapping was completed.

Figure 7 illustrates the stratigraphy of drill holes 92RN-1 and 92RN-3. In hole 92RN-1 175 metres of dark and light grey, banded marble, graphitic marble and lesser calcsilicate structurally overlie 30 metres of dark calcareous phyllite and cherty phyllite. The calcareous rocks can be divided into an upper, relatively clean marble and lower graphitic marble and calcareous phyllite. The underlying dark phyllitic units contain massive sulphide lenses and disseminated sulphides, and a graphitic zone containing a few percent pink spessartine garnets to 2 millimetres diameter. Light brown to grey, biotite-quartz-sericite schist, metadiorite sills, and lesser calcsilicate layers and quartzite occupy the bottom of the section.

Light grey, banded marble also overlies graphitic dark phyllites in hole 92RN-3. The transition from marble to the graphitic phyllite is abrupt and marked by pyrrhotite lenses and a garnet zone in cherty, graphitic phyllite immediately below the contact. Rhythmic-layered centimetre-scale beds of graphitic phyllite and carbonate (calcareous phyllite), light grey, banded marble, and green sericite schist separate the upper garnet zone from another black, cherty graphitic phyllite which contains two narrow garnet zones The remainder of the hole cuts a monotonous package of calcareous phyllite with layers of banded marble and minor dark phyllite. These carbonates contrast with the biotite-sericite schists which underlie the dark phyllite and garnet zone in hole 92RN-1 and make correlation of the two holes difficult. Attitudes of compositional layering relative to the core axis change frequently and probably reflect significant folding.

Dark calcareous and graphitic phyllite and sericite schist underlie the area of Murder Creek. Massive, light grey, banded marble forms the ridge to the west and structurally underlies the dark phyllites exposed in the creek. Thinly interbedded phyllite and carbonate correspond to the calcareous phyllite in the drill holes. Coarse disseminated, stratabound pyrite is common in some graphitic units and Wild (1990) describes a garnet zone within these rocks. The dark phyllite/sericite schist is strongly contorted adjacent to the contact with underlying marble and overprinted by a quartz vein stockwork. The contact appears to be faulted; if it is not, then the strata is opposite to that in the drill holes, and stratigraphy must turn over in an unrecognized fold between the creek and the holes. Massive quartzite appears to underlie the marble on the ridge west of Murder Creek.

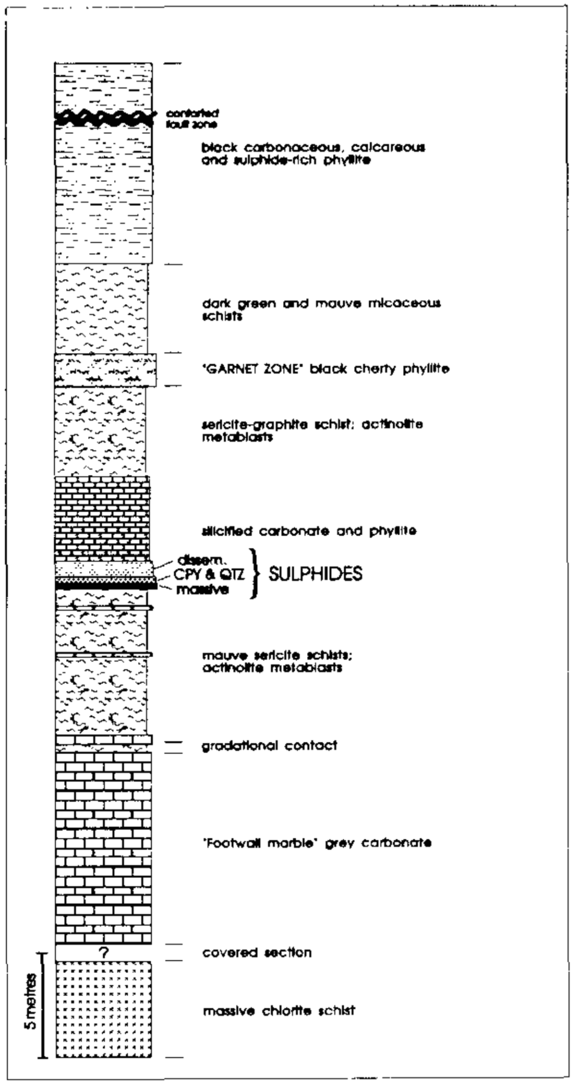

Figure 6. Measured stratigraphic section of the east wall of the Goldstream mine open pit

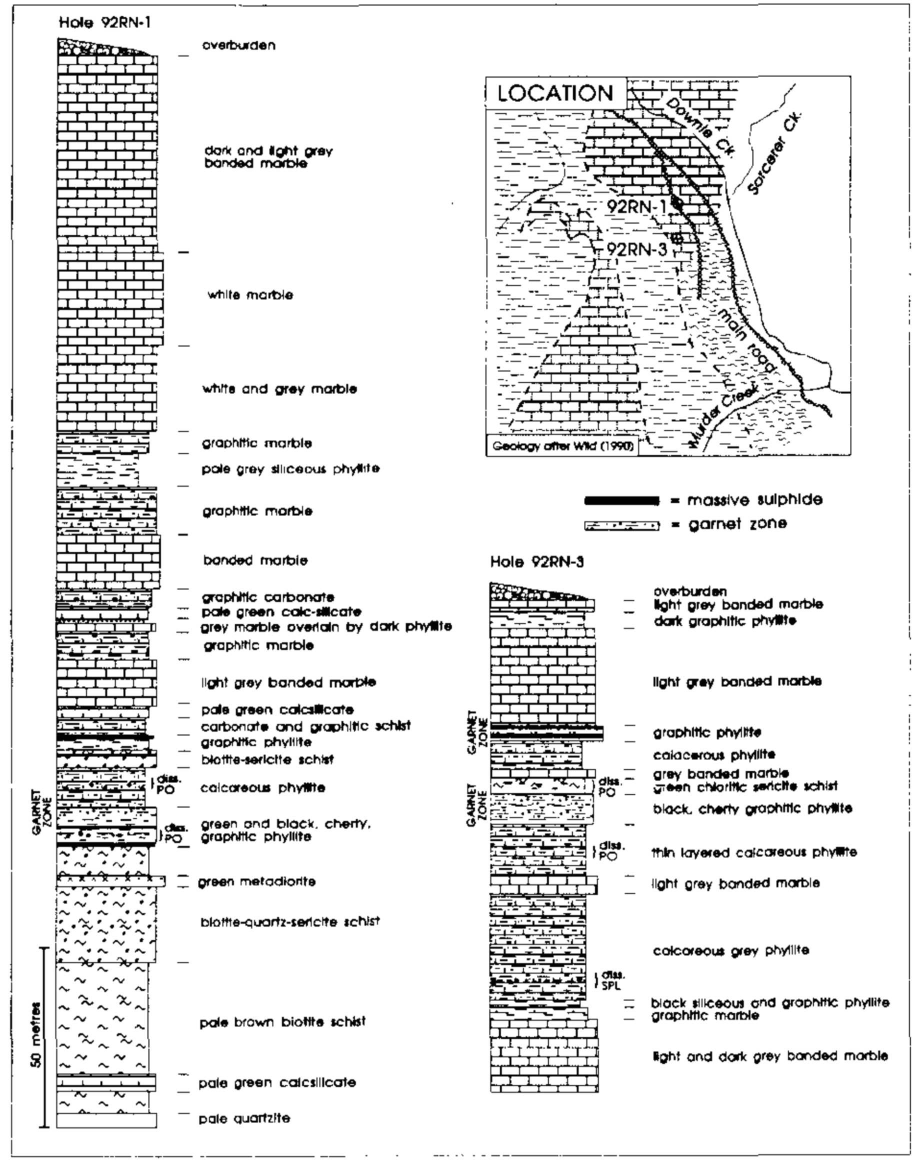

Figure 7. Stratigraphy of drill holes 92RN-1 and 92RN-3 on the Rain property between Standard and Murder creeks. PO=pyrrhotite, SPL=sphalerite.

MONTGOMERY

The Montgomery property is located approximately 12 kilometres southeast of the Goldstream mine (Figure 3). The showings comprise a series of massive and disseminated sulphide lenses in micaceous quartzose schist and carbonaceous sericite-chlorite phyllite interlayered with carbonates. Felsite apophyses from the Long Creek stock crosscut the succession and skarn calcareous units. Sulphides have been traced intermittently by trenching for 770 metres (Schindler, 1982). The sulphides consist of several lenses of massive pyrrhotite up to 3 metres thick, with minor amounts of chalcopyrite, sphalerite and trace galena. The massive sulphide horizon contains clear, rounded fragments of quartz and dark green chlorite inclusions identical to Goldstream ore. Hangingwall rocks are quartz-rich graphitic and rusty weathering biotite-sericite schist that contain coarse stringers of chalcopyrite and pyrrhotite. The footwall to the sulphides is mafic chlorite-biotite-quartz schist and calcsilicate. Two diamond-drill holes were completed in October of 1990 (Campbell and Lewis, 1991) to test the down-dip extension of the massive sulphides exposed at the adit. The drill core was logged after visiting the adit and tracing out the sulphide horizons on surface (Figure 8). The holes penetrated a series of calcsilicate units within biotite-quartz-sericite schist. Massive sulphide horizons occur between felsite sills or within thinly intercalated biotite-schist and calcsilicate.

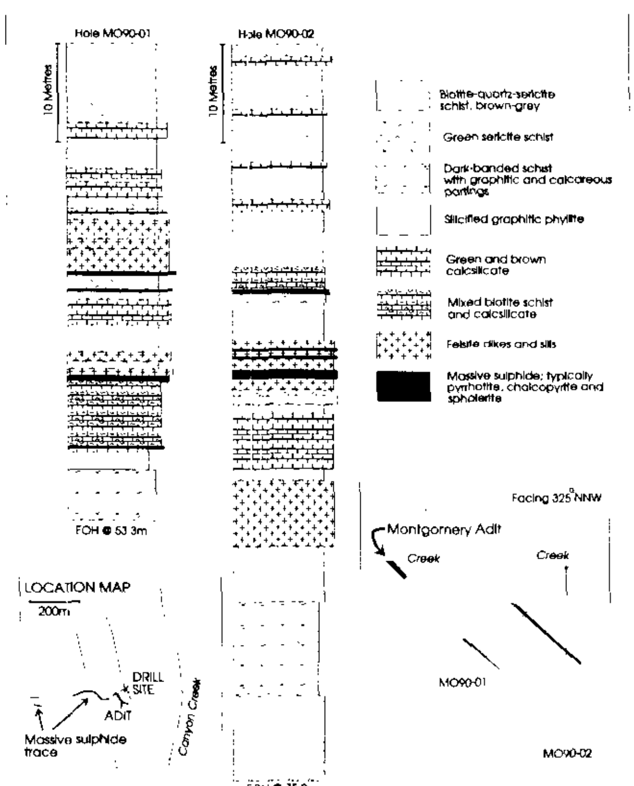

Figure 8. Stratigraphy of drill holes MO-90-01 and MO-90-02 on the Montgomery property between Canyon and Boulder creeks.

The host rocks are higher metamorphic-grade equivalent rocks to those at the Goldstream mine and Rain occurrence. They represent another mineralized horizon in the stratigraphy. Reconnaisance mapping in the Montgomery area identified a number of rusty horizons with pyrite-pyrrhotite and occasional chalcopyrite.

STANDARD

The Standard showings are located on the east side of Standard Peak and consist of a series of discontinuous pyrrhotite-pyrite-chalcopyrite-sphalerite lenses in green volcanic-derived feldspathic sandstone and black graphitic phyllite. Sill-like bodies of serpentinite and talc schist intrude along the contacts of these units and are spatially associated with sulphide occurrences. The structure in the area consists of a north-plunging, east-dipping overturned antiform which repeats strata and sulphide lenses (Höy *et al.*, 1984). The sulphides are traceable intermittently for 1500 metres along strike. The stratigraphic position of several adits is shown on Figure 9. The rocks are correlated with basic metavolcanic rocks and phyllite of the upper Index Formation (Brown *et al.*, 1983). Two stratigraphic sections containing sulphide occurrences, were measured on the east limb of the anticline. Figure 9 is a composite section of the west limb and structurally underlying rocks.

The symmetrical distribution of grey foliated carbonate, dark phyllite and chlorite schist around a 10-metre hinge zone of dark phyllite defines the Standard Peak antiform. The east limb is apparently thinned relative to the west. The west limb consists of 10 to 15 metres of grey foliated carbonate and about 5 metres of buff-weathering dolomite structurally underlain by 20 to 30 metres of dark phyllite. The dark phyllite is identical to black sericite schists interlayered with carbonate units at Keystone Peak, Downie Creek and Goldstream River. The most common unit at Standard Peak is massive chlorite schist, which underlies the dark phyllites on the west limb and overlies them on the east limb. In places the schist contains flattened gneissic fragments that may represent relict flow breccia. The chlorite schist contains thick intervals of black and green phyllite, feldspathic sandstone and volcanic wacke and rare medium-grained, foliated metadiorite bodies. It is structurally underlain to the west by grits and dark phyllites, followed by thinly bedded calcareous green-grey tuff and quartzofeldspathic psammitic schist. At least 5 metres of pink quartzite overlies the chlorite schist on the east limb.

Sill-like, boudinaged sheets of serpentinite and talc schist up to 30 metres thick intrude along or near the contacts of dark phyllite and massive chlorite schist and dark phyllite and carbonate. On the west

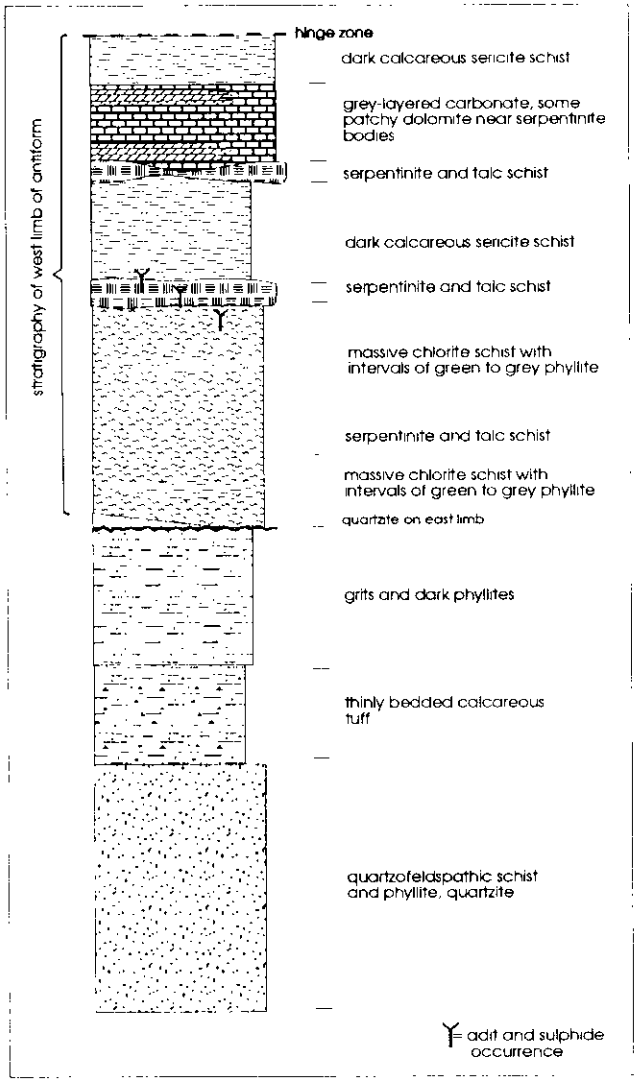

Figure 9. Schematic stratigraphy at Standard Peak. The succession above the Standard Peak thrust fault (heavy undulating line) forms the western limb of the north-trending and plunging Standard antiform.

limb of the antiform, the thickest and most continuous sill crosscuts foliation and stratigraphy. The other ultramafic bodies appear to be conformable. Similar ultramafic rocks occur in the Keystone area along the contact of chlorite schist and dark phyllite.

OTHER MINERAL OCCURRENCES

North of the Goldstream River, three active placer gold mining operations were conducted, one on French Creek and two on McCulloch Creek. Gold-tungsten and base metal quartz veins that crosscut regional penetrative foliation occur in the headwaters of these two creeks. Stratabound mineralization was not encountered.

EXPLORATION GUIDELINES

The copper-zinc deposits of the Goldstream area occur in dark graphitic schists, sericite schists and calcareous phyllites associated with actinolite schists (Table 2). They are interpreted to have formed in a rifted marginal or back-arc basin, in contrast with the numerous lead-zinc deposits which occur in platformal rocks of southeastern British Columbia (Höy, 1982). The copper-zinc deposits are similar to the Besshi-type deposits in Japan (Höy *et al.*, 1984; Höy 1991), which characteristically occur within either mafic volcanic rocks (typically tholeiitic) or terrigenous clastic rocks interlayered with flows or sills.

A number of diagnostic features characterize Besshi-type deposits (Slack, in press). Table 2 compares these features with those of massive sulphide deposits in the area. The features include: a generally sheet-like morphology within clastic marine sediments and minor mafic volcanic rocks; a sulphide mineralogy consisting of mainly pyrite and/or pyrrhotite, minor chalcopyrite and sphalerite and very little galena; relatively high contents of cobalt and Co/Ni ratios. In addition, distinctive wallrock lithologies including metachert, magnetite iron formation, coticule (fine-grained spessartine-quartz rock), tourmalinite, albitite and chlorite and sericite-rich schist are common (Slack, in press). These lithologies result from alteration by, or direct precipitation from, hydrothermal fluids related to ore deposition and therefore provide useful exploration targets.

In the Goldstream area, a distinctive spessartine-bearing, pyrrhotite-rich, thin-laminated graphitic coticule unit termed the 'garnet-zone' is associated with the massive sulphide layer. The garnet zone is interpreted to be a manganese-iron-rich seafloor hydrothermal precipitate; an exhalite (Höy *et al.*, 1984). Garnet zone also occurs at the Rain property and west of the Long Creek stock. No garnet zone has been recognized at the Standard or Montgomery showings. Chlorite and sericite-rich phyllites enclose the massive sulphide layer, and schists are common to all occurrences in the study area. Extrusive volcanic rocks, with the exception of the Standard area, are rare. Sparse, but ubiquitous greenstones are actinolite metadiorite dikes or sills, common features in Besshi deposits. Sulphide mineralogies are consistent but there is little data on cobalt and nickel contents for the ores.

Current stratigraphic correlations indicate the mineral deposits are hosted at three different horizons in the Index Formation. The Goldstream and Rain occur lowest and the Montgomery higher in a mainly sedimentary sequence. The Standard is hosted in a volcanic dominated sequence higher in the formation.

Tourmalinites are closely associated with coticules (garnet zone) in sequences containing clastic metasedimentary and mafic metavolcanic rock (Slack, 1993). The preservation of iron-manganese-boron

TABLE 2. COMPARISION OF THE CHARACTERISTICS OF BESSHI TYPE DEPOSITS WITH MASSIVE SULPHIDE OCCURRENCES IN THE STUDY AREA.

BESSHI TYPE DEPOSITS (after Slack, in press)	GOLDSTREAM	MONTGOMERY	STANDARD	RAIN
Sheet-like morphology, within				
clastic marine sediments,	yes	yes	yes	yes
minor mafic volcanic rocks,	?	no	yes	?
or metadiorite sills	yes	yes	yes	yes
Sulphide mineralogy of mainly pyrite and/or pyrrhotite, with minor chalcopyrite and sphalerite	yes	yes	yes	yes
High Co content, high Co/Ni ratio	no	?	?	?
Distinctive wall rocks:				
• metachert	yes	?	?	yes
• coticule (garnet zone)	yes	no	no	yes
• albite	?	?	?	?
• chlorite and sericite schist	yes	yes	yes	yes

exhalites may require venting into a thermally and chemically isolated brine pool (Slack *et al.*, 1993), conditions also necessary for sulphide accumulation. These garnet zones are important viable exploration targets. Work this summer measuring sections resulted in the discovery of a new garnet zone located midway between the Rain property and the Goldstream mine emphasizing the fact that the area is under explored and incompletely mapped.

The relationship of ultramafic rocks with the apparently stratabound, volcanogenic mineralization at Goldstream and Standard is not known. Both may be indicative of crustal-scale faults capable of tapping deep circulating hydrothermal fluids and ultramafic intrusive melts.

CORRELATIONS AND CONUNDRUMS

The stratigraphy of the Goldstream slice of the Selkirk allochthon correlates well with lower and middle packages of the Eagle Bay assemblage in the Adams Lake-Clearwater area (Schiarizza and Preto, 1987). Correlations are based on the archaeocyathid-bearing limestones of the Tshinakin (Eagle Bay assemblage) and the Badshot limestone of the Kootenay Arc. Associated with the Tshinakin limestone are mainly calcareous chlorite schists derived from mafic volcanic rocks. Structurally below the limestone are siliceous and graphitic phyllite, limestone and quartzite (unit EBGs of Schiarizza and Preto, 1987) similar to the section exposed northwest of the Goldstream mine. The metasedimentary rocks of unit EBGs host lead-zinc-silver mineralization on Adams Plateau and similar stratabound showings (C-1, C-2 and C-3) have recently been discovered by Bethlehem Resources Corporation in the above mentioned section. Polymetallic precious and base metal massive sulphide deposits (*e.g.* Homestake, Rea) are associated with Devono-Mississippian intermediate to felsic volcanism in the Eagle Bay assemblage. These Kuroko-type deposits could be outboard, arc-equivalent deposits of the marginal basin Besshi-type Goldstream deposit and, if so, suggest the Goldstream deposit is Devonian in age as the preliminary lead-isotope model ages infer (Höy *et al.*, 1984).

The stratigraphy of the Lardeau Group has been studied in the type area by Smith and Gehrels (1992a) and correlated with Cordova Group and Bradeen Hill assemblage to the south, in northeastern Washington (Smith and Gehrels, 1992b). Their correlation suggests that the established stratigraphy of the Lardeau Group as defined by Fyles and Eastwood (1962) is inverted and suggest the Broadview Formation is the oldest and the Index Formation the youngest unit of the Lardeau Group. Devonian age fossils from the Bradeen Hill assemblage, correlative with the Index Formation, and the Early to Middle Ordovician Rb-Sr whole-rock isochron date from boulders of the Broadview Formation (Read and Wheeler, 1977) support this contention. Neither fossils nor contact relations which would permit addressing this aspect of the stratigraphy were recognized this year.

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NOTES